INSTRUCTION MANUAL

CRYSTAL-BOLOMETER AMPLIFIER

MODEL CBA 21

SERIAL NO. 30.1

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SCIENTIFIC-ATLANTA, INC.
P. O. BOX 13654, ATLANTA 24, GEORGIA (3845 Pleasantdale Road—at NE Expressway)
Telephone 404-938-2930 • TWX: 404-938-1322 • WUX • Cable SCIATLA

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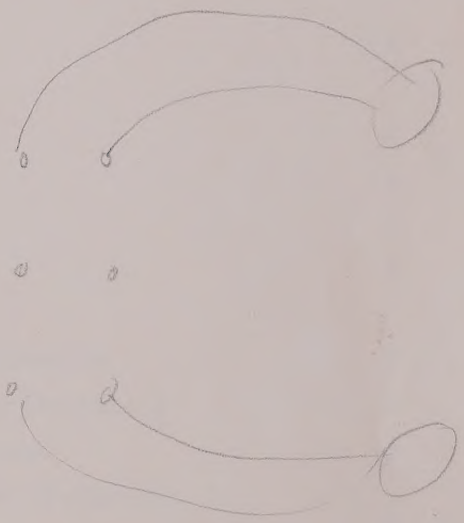

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MODEL CBA 21

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I. GENERAL DESCRIPTION

1.1 Introduction

The Model CBA 21 Crystal-Bolometer Amplifier is a miniature plug-in unit designed for use as a preamplifier with the Scientific-Atlanta, Incorporated, Series APR 20 Rectangular and APR 30 Polar Pattern Recorders. This unit is a sensitive narrow-band amplifier which may be operated from the output of a crystal detector or a bolometer detector. The center frequency of the amplifier is determined by a single plug-in filter package. Filter packages are avaible at any selected frequency between 500 cps and 2500 cps. The unit is normally furnished with a 1000 cps filter unless a special frequency is requested.

A front panel meter provides monitoring of bolometer bias current during operation with a bolometer detector. A bolometer overload protection circuit minimizes the chance of bolometer burnout should the bolometer connection be broken and reconnected with bolometer bias applied.

1.2 Specifications

Gain	
Crystal Input	92 db
Bolometer Input	100 db
Input Impedance	
Crystal Input	5000 ohms
Bolometer Input	1000 ohms
Center Frequency (Standard)	1000 cps
Bandwidth (3 db)	± 20 cps
Noise Level (Equivalent Input)	0.02 μ volts
Bolometer Bias (Range)	0-10 ma.
Bolometer Current Meter (Range)	0-10 ma.

Attenuation*	
Fixed	Three 20 db steps
Variable	0-20 db
Attenuation Accuracy (Fixed)	±0.1db
Dynamic Range	80 db
Input Connectors (front and rear)	BNC
Plate Supply Requirements	+ 250 v at 15 ma. + 150 v at 16 ma.
Filament Supply Requirements	- 12 v dc at 0.5 amp
Front Panel Size	4.25" x 7.63"

II. OPERATING INSTRUCTIONS

2.1 Operation From a Crystal Detector

For operation of the Crystal-Bolometer Amplifier from the detected audio output of a crystal detector, place the CRYSTAL-CURRENT-BOLOMETER switch in the CRYSTAL position. Connect the output of the crystal mount by means of a length of coaxial cable to either the front panel CRYSTAL INPUT connector (J2A-3) or the rear CRYSTAL INPUT connector (J1A-3). With an amplitude modulated rf signal applied to the detector, adjust the modulation frequency to correspond to the center frequency of the Crystal-Bolometer Amplifier. This will be indicated by maximum recorder pen deflection. The fixed and variable gain controls may be set to obtain the desired recorder sensitivity.

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* All 20 db attenuation ranges are labeled as 10 db ranges to correspond to the signal variation on the rf side of a square-law detector.

2.2 Operation From a Bolometer Detector

For operation of the Crystal-Bolometer Amplifier from the detected audio output of a bolometer detector, place the CRYSTAL-CURRENT-BOLOMETER switch in the CURRENT position. Turn the BOLOMETER CURRENT ADJUST control fully counterclockwise. Connect the output of the bolometer mount by means of a length of coaxial cable to either the front panel BOLOMETER INPUT connector (J2-3) or the rear BOLOMETER INPUT connector (J1-3). While observing the meter, turn the BOLOMETER CURRENT ADJUST control clockwise until the recommended bolometer current level is reached (between 0 and 10 ma.). Place the CRYSTAL-CURRENT-BOLOMETER switch in the BOLOMETER position. This removes the meter from the bolometer circuit eliminating noise generated by meter vibration.

With an amplitude modulated rf signal applied to the bolometer, adjust the modulation frequency to correspond to the center frequency of the Crystal-Bolometer Amplifier. This will be indicated by maximum recorder pen deflection. The fixed and variable gain controls may be set to obtain the desired recorder sensitivity.

Note: A voltage limiting circuit is included as part of the bolometer bias circuit. This circuit prevents the possibility of bolometer burnout if the bolometer is disconnected and reconnected with bias applied.

2.3 General Operating Precautions

To obtain maximum sensitivity from the Crystal-Bolometer Amplifier, care should be taken to eliminate excessive 60 cps pickup in the input cable. The interference may cause slow beating of the recorder pen at low values of signal input level. Although the Crystal-Bolometer Amplifier has very high rejection to 60 cps input voltages, the extreme sensitivity of this amplifier will permit large values of 60 cps input voltages to be detectable in the presence of low levels of input signal.

The Crystal-Bolometer Amplifier and Antenna Pattern Recorders are designed to minimize all internal sources of noise and 60 cycle hum pickup. The pattern recorder includes a well filtered dc filament supply which is used for all sensitive amplifier stages. All ground circuits are arranged to eliminate ground loops which could result in inter-circuit coupling. Adequate electrostatic and magnetic shielding is provided throughout the pattern recorder. The Crystal-Bolometer Amplifier is housed in a high-permeability case when mounted in the pattern recorder.

Hum at the amplifier input, exclusive of any which may be associated with the received signal, occurs when 60 cycle currents of an appreciable value are permitted to flow in the shield of the coaxial cable connecting the Crystal-Bolometer Amplifier input connectors to the detector. This effect is noticeable when the detector mount is connected to a ground system which is not at zero potential with respect to the pattern recorder ground. The pattern recorder is furnished with a ground connection at the power plug. This ground should be connected to a separate ground wire, not ac common.

Unwanted 60 cycle pickup can occur if the coaxial cable connecting the detector mount to the Crystal-Bolometer Amplifier is run in the vicinity of 60 cycle magnetic fields. A power cable run beside the input coaxial cable will induce 60 cycle currents in the shield. To reduce 60 cycle pickup effects to a minimum, proper grounding or complete isolation of the detector mount from ground is necessary; in addition, adequate isolation of the interconnecting coaxial cable from magnetic fields is necessary.

The effects of unwanted currents flowing in the shield of the input cable can be minimized by use of a triaxial input cable. If the inner and outer shields are tied together at the detector end and connected to the shell of a BNC connector, a coaxial connection can be made to the detector. At the Crystal-Bolometer Amplifier input, the inner shield and the center conductor should be connected to a BNC connector for connection to the input and the outer shield should be connected to a test lead plug and connected to the triaxial ground jack provided on the front of the amplifier. A triaxial cable which is satisfactory for this purpose is the Type 21-204.

The length and type of coaxial cable which is used between the detector mount and the Crystal-Bolometer Amplifier may vary considerably. The effects of cable length on pattern recorder operation are those relating to hum pickup and signal deterioration. Cable lengths of several thousands of feet may be used without undesirable effects provided the cable is properly isolated from magnetic and electrostatic fields. An excellent coaxial cable for use between the detector mount and the Crystal-Bolometer Amplifier is type RG-62/U. This cable is recommended because of its small size, flexibility, high impedance, and low capacity; however, many other cables are suitable and may be used.

2.4 Parallel Operation of Crystal-Bolometer Amplifiers

It is often convenient to operate two pattern recorders simultaneously from one detector mount. This is desirable to permit simultaneous plotting of either two pen functions and/or of a polar and a rectangular pattern. To permit parallel operation of Crystal-Bolometer Amplifiers, the CRYSTAL INPUTS are capacity coupled to the input transformer.

The procedure for parallel operation is as follows:

a. For operation from either a crystal detector or a bolometer detector, connect one Crystal-Bolometer Amplifier as described in Section 2.1 or 2.2.

b. Break the coaxial line between the detector mount and the INPUT of the Crystal-Bolometer Amplifier and add a coaxial tee connector.

c. Connect the third arm of the coaxial tee by means of a coaxial cable to one of the CRYSTAL INPUTS located on the second Crystal-Bolometer Amplifier.

d. Place the CRYSTAL-CURRENT-BOLOMETER switch of the second amplifier in the CRYSTAL position.

e. Both Crystal-Bolometer Amplifiers may now be independently adjusted to provide the desired recording sensitivities.

Note: Parallel operation will reduce the overall gain of each Crystal-Bolometer Amplifier by less than 6 db.

2.5 Amplifier Overload Indicator

The Crystal-Bolometer Amplifier is provided with a neon lamp to indicate when the amplifier saturation level is reached. The amplifier will never reach saturation when the pattern recorder pen is on scale and the overload indicator is not necessary for normal recorder operation.

It is possible, however, when using the signal level meter located on the front panel of the Function Amplifier, to overdrive the Crystal-Bolometer Amplifier and still be at less than full scale on the meter. Under this condition the meter scale will be inaccurate. To prevent this possibility, always operate the Crystal-Bolometer Amplifier at an output level below saturation and use the separate attenuators associated with the signal level meter to obtain the desired meter deflection.

2.6 Amplifier Bandwidth Considerations

The overall frequency response of the Crystal-Bolometer Amplifier tuned to a center frequency of 1000 cps is shown by Figure 1. As is indicated, the half-power bandwidth is 40 cps and the rejection to 60 cps is greater than 80 db.

It is occasionally necessary to operate two nearby pattern ranges at frequencies within the same band incurring difficulties due to inter-range interference. This situation may be improved by providing different audio modulation frequencies for each pattern range transmitter. By spacing of the modulation frequencies sufficiently to obtain a maximum rejection of the interfering signal by each Crystal-Bolometer Amplifier, the interference effect is minimized. For example, considering the shape of the frequency response curve of Figure 1, if two Crystal-Bolometer Amplifiers were selected at center frequencies of 800 cps and 1000 cps, then the 800 cps amplifier will provide approximately 45 db rejection to 1000 cps and the 1000 cps amplifier will provide 50 db rejection to 800 cps and 40 db rejection to the second harmonic 1600 cps.

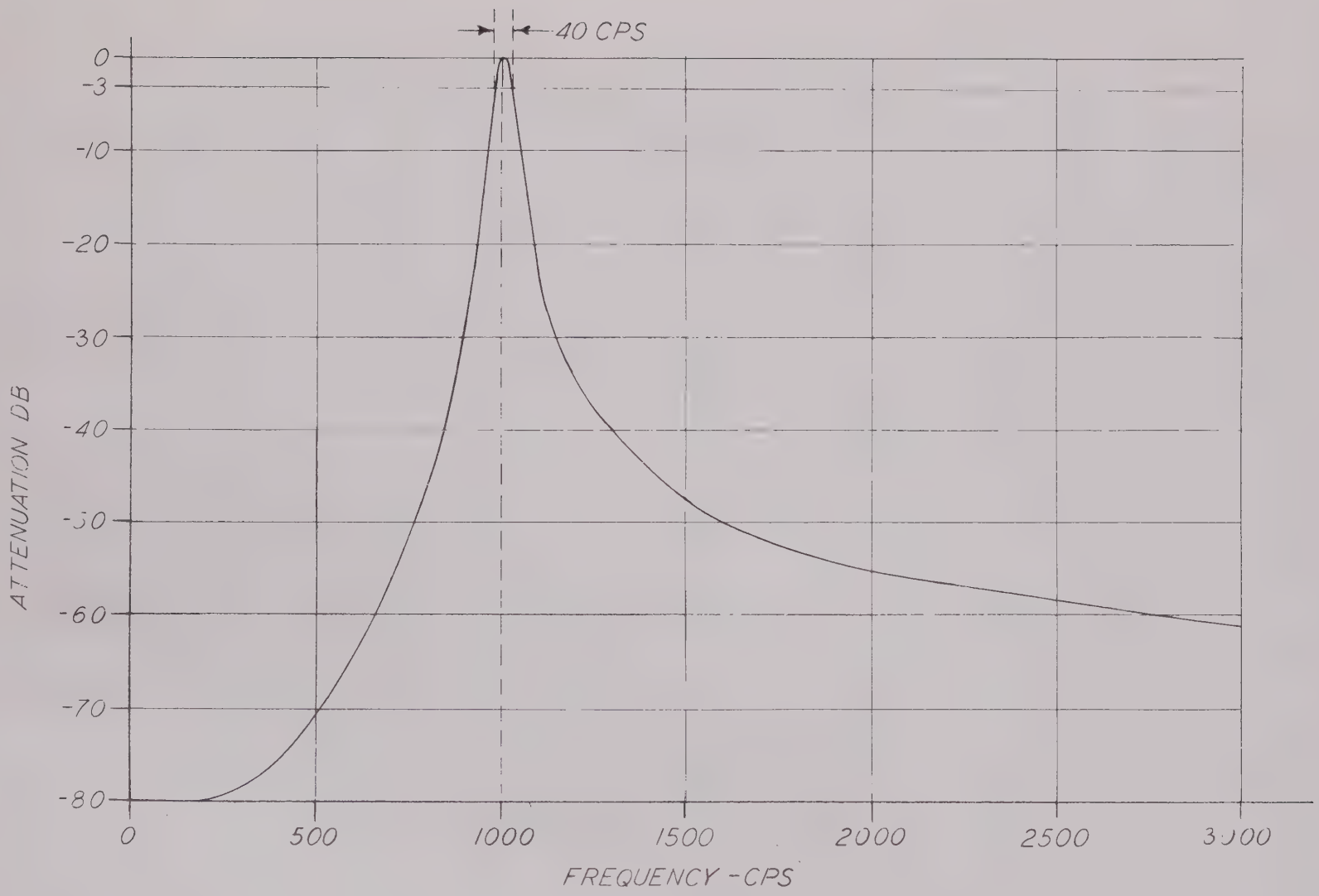

Figure 1. Frequency Response of Crystal-Bolometer Amplifier (Center frequency = 1000 cps).

III. DETAILED DESCRIPTION

3.1 Input Circuit

A circuit diagram of the Crystal-Bolometer Amplifier is shown by Figure 2. The amplifier is furnished with separate crystal and bolometer front and rear panel BNC coaxial connectors. These crystal inputs are capacity-coupled to a high-impedance tap of the input transformer.

When operating from a crystal detector, S2-3 is placed in the CRYSTAL position, returning terminal 3 of the input transformer (T1-3) to the coaxial input ground. The crystal detector input at either J1A-3 or J2A-3 is capacity-coupled to terminal 1 of T1-3 providing a 5000 ohm input impedance.

To provide for adjustment of a bolometer detector bias level, S2-3 is placed in the CURRENT position. R25-3 is the BOLOMETER CURRENT ADJUST potentiometer which provides a range of bias current from 0 to 10 milliamperes with most standard bolometers. The CURRENT position of S2-3 is used only for monitoring bolometer bias current; S2-3 should be placed in the BOLOMETER position for operation. In this position of S2-3, the meter M1-3 is removed from the circuit to eliminate noise generated in the meter due to mechanical vibration.

C7-3 provides a low impedance signal return from terminal 2 of T1-3 to ground during operation in the BOLOMETER position of S2-3. The resistor (R24-3) and diode (CR1-3) provide limiting of the voltage to which C7-3 charges with the amplifier input disconnected. This prevents bolometer burnout if the bolometer is connected with bias applied.

Input transformer (T1-3) provides an input impedance of 1000 ohms at the bolometer input.

3.2 Intermediate Stages

The step attenuator (S1-3) provides three 20 db fixed attenuation steps in addition to an OFF position. Each attenuation step is located at a separate point in the amplifier to prevent amplifier overload. A variable attenuation of 20 db is provided by potentiometer (R4-3) which determines the amount of negative feedback coupled from the plate to the grid of the first half of V1-3. Both halves of V1-3 are low noise resistance coupled amplifiers. The 6072 (a ruggedized version of the 12AY7) has low noise, low filament hum pickup and has very low microphonics. Wirewound plate load resistors (R8-3 and R9-3) are used to minimize noise generated within these components.

The first half of V2-3 is a cathode follower which isolates the low impedance input of the narrow-band filter (FL1-3) from the step attenuator. FL1-3 is a bandpass filter and may be selected at any center frequency between 500 cps and 2500 cps. Unless otherwise specified this filter is furnished at a center frequency of 1000 cps.

3.3 Output Circuit

The second half of V2-3 is a resistance coupled amplifier which drives the power amplifier (V3-3). The signal at the plates of V3-3 is degeneratively coupled to the plate of the second half of V2-3 by R17-3. T2-3 has two outputs: terminal 5 to terminal 4 provides a 600 ohm output impedance and a maximum output of 10 volts rms, terminal 7 to terminal 4 provides a 50 ohm output impedance and a maximum output of 3 volts rms. The 600 ohm output connection is available at J3-3 for monitoring. During normal operation with the pattern recorder, the 600 ohm output connection is used to drive the logarithmic-function recorder circuits and the 50 ohm output connection is used to drive the square-root-function and linear-function recorder circuits.

The AMPLIFIER OVERLOAD indicator (NE1-3) is a neon lamp connected to the plate of the output amplifier V3-3 by means of C8-3 and R28-3. This lamp glows when the output of the amplifier approaches the saturation level of the output stage (V3-3). This saturation level is

approximately 3 db above the output level of the Crystal-Bolometer Amplifier required to provide full scale logarithmic pen deflection of the pattern recorder.

All output signal and input power connections to the Crystal-Bolometer Amplifier are made through connector (P4-3). The filament voltage and plate supply voltages are obtained from the pattern recorder. A filament supply of -12 volts, 0.5 amp and plate supplies of + 250 volts at 15 ma and + 150 volts at 16 ma are required.

The Crystal-Bolometer Amplifier is designed for low hum pickup. The internal chassis is isolated from the front panel to prevent the occurrence of ground current loops (three parts are connected together by a 10 ohm resistor). T1-3 and FL1-3 have high-permeability shielding. The entire Crystal-Bolometer Amplifier is housed in a high-permeability case when plugged into the pattern recorder. Throughout, dc filaments are used to minimize 60 cps pickup.

IV. MAINTENANCE

4.1 General

In the event of faulty operation of any part of the Crystal-Bolometer Amplifier a visual inspection of tubes, cable connections, and other components should be completed first. Afterward, standard maintenance procedures should be followed to isolate the trouble to a particular stage and then to the defective component. To aid in the maintenance, the circuit diagram provides typical plate voltages and current values, component values and part numbers. In addition, the following voltage and gain tables provide a means of testing the static and dynamic circuit operation.

4.2 Static Measurements

The following table provides typical values of dc voltage present at the tube pins of the amplifier stages. These voltages are measured with respect to ground using a 20,000 ohm-per-volt voltmeter. These voltages are subject to standard tolerances of ± 10%. During measurement the ATTENUATOR should be set to the OFF position.

TABLE I D C VOLTAGES

Tube Numbers	Pin Numbers								
	1	2	3	4	5	6	7	8	9
V1-3	+175	0	+2.4	0	-12	+175	0	+2.4	-6.0
V2-3	+215	0	+2.9	0	-12	+205	0	+4.8	-6.0
V3-3	+242	+6.2	+12	0	-12	+242	+6.2	+12	-6.0

4.3 Dynamic Measurements

The following tabulation (Table II) provides typical values of voltage-gain-per-stage for the crystal-bolometer amplifier. These measurements were made with both attenuators set to the minimum attenuation positions. These values of gain were taken from a standard amplifier with a 1000 cps center frequency and 1000 cps signal applied to the input.

TABLE II GAIN

Gain Measured		Voltage Gain
From	To	
J1-3 or J2-3	Pin 7, V1-3	27 db
Pin 7, V1-3	Pin 2, V1-3	23 db
Pin 2, V1-3	Pin 7, V2-3	23 db
Pin 7, V2-3	Pin 2, V2-3	4 db
Pin 2, V2-3	Pin 2, V3-3	9 db
Pin 2 or 7, V3-3	J3-3	16 db

PARTS LIST

MODEL CBA 21 CRYSTAL-BOLOMETER AMPLIFIER

MANUFACTURERS' CODE LETTERS

Code	Manufacturer
A	Aerovox
AB	Allen-Bradley
AE	Amphenol
BLI	Bourns
BUR	Burnell
CD	Cornell-Dublier
CH	Cutler-Hammer
CRL	Centralab
DE	Dage
DP	Dale
GE	General Electric
O	Ohmite
P	Pace Electrical Instruments
SE	Simpson
T	Triad
TE	Transitron
TO	Tru-Ohm

PARTS LIST

MODEL CBA 21 CRYSTAL-BOLOMETER AMPLIFIER

Component Designation	Description	Mfr. *	Mfr. Part No.
C1-3 C6-3 C9-3	Capacitor: fixed, electrolytic, 25 µf, 25 vdcw	A	PWE 25025
C1A-3	Capacitor: fixed, paper, 0.47 µf, 100 vdcw	CD	WMF1P47E
C2-3 C3-3 C5-3	Capacitor: fixed, paper, 0.047 µf, 400 vdcw	CD	WMD4547E
C4A/B/C-3	Capacitor: fixed, electrolytic, 10-10-10 µf, 300 vdcw	A	AFH 3-22
C7-3	Capacitor: fixed, electrolytic, 200 µf, 6 vdcw	A	PWE 6200
C8-3	Capacitor: fixed, paper, 0.01 µf, 400 vdcw	A	P488 N
C10-3	Capacitor: fixed, ceramic, 100 µµf, 500 vdcw ± 20%	A	SI-1
CR1-3	Diode: silicon	TE	1N811
FL1-3	Filter: plug-in, 1000 cps	BUR	S-57088
J1-3 J1A-3 J2-3 J2A-3 J3-3	Connector: BNC	DE	UG-657/U
M1-3	Meter: 0-10 milliamperes dc	P	25-LPB
NE1-3	Bulb: neon	GE	NE-2
P4-3	Connector: miniature	AE	165-11
R1-3	Resistor: fixed, composition 10 ohms, 10%, 1/2 watt	O	"Little Devil"
R2-3	Resistor: fixed, deposited carbon, 900 k ohms, 1%, 1/4 watt	DP	DCH 1/4
R3-3	Resistor: fixed, deposited carbon, 100 k ohms, 1%, 1/4 watt	DP	DCH 1/4
R4-3	Resistor: variable, wire-wound, 10 turns, 50 k ohms, 5%, 2 watts, 0.25% linearity	BLI	3500S-30-503

*See "MANUFACTURERS' CODE LETTERS"

PARTS LIST - Continued

CRYSTAL - BOLOMETER AMPLIFIER

Component Designation	Description	Mfr.*	Mfr. Part No.
R5-3 R28-3	Resistor: fixed, composition 22 k ohms, 10%, 1/2 watt	O	"Little Devil"
R6-3	Resistor: fixed, composition 1.2 k ohms, 10%, 1/2 watt	O	"Little Devil"
R7-3 R15-3	Resistor: fixed, wirewound 1.2 k ohms, 3 watts	TO	VAL-3
R8-3 R9-3 R14-3 R16-3	Resistor: fixed, wirewound 15 k ohms, 3 watts	DP	RS-2B
R10-3	Resistor: fixed, deposited carbon 180 k ohms, 1%, 1/4 watt	DP	DCH 1/4
R11-3	Resistor: fixed, deposited carbon 20 k ohms, 1%, 1/4 watt	DP	DCH 1/4
R12-3	Resistor: fixed, deposited carbon 5 k ohms, 1%, 1/4 watt	DP	DCH 1/4
R13-3	Resistor: fixed, deposited carbon 45 k ohms, 1%, 1/4 watt	DP	DCH 1/4
R14A-3	Resistor: fixed, composition 10 k ohms, 10%, 1/2 watt	O	"Little Devil"
R17-3	Resistor: fixed, composition 270 k ohms, 10%, 1/2 watt	O	"Little Devil"
R18-3	Resistor: fixed, composition 10 k ohms, 10%, 2 watts	O	"Little Devil"
R19-3	Resistor: fixed, composition 1 k ohm , 10%, 1 watt	O	"Little Devil"
R20-3	Resistor: fixed, composition 120 k ohms, 10%, 1/2 watt	O	"Little Devil"
R21-3 R22-3	Unassigned		
R23-3	Resistor: fixed, composition 1.5 k ohms, 10%, 1 watt	O	"Little Devil"
R24-3	Resistor: fixed, wirewound 200 ohms, 3 watts	TO	VAL-3

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST - Continued

CRYSTAL - BOLOMETER AMPLIFIER

Component Designation	Description	Mfr.*	Mfr. Part No.
R25-3	Resistor: variable, composition 1 k ohms, 10%, 2 watts	O	CLU-1021
R26-3	Resistor: fixed, wirewound 4 k ohms, 3 watts	TO	VAL-3
R27-3	Resistor: fixed, wirewound 5 k ohms, 3 watts	TO	VAL-3
R30-3	Resistor: fixed, wirewound 0.47 ohms, 1/2 watt	AB	BW
S1-3	Switch: rotary, 6 position 4 circuits	CRL	PA-2010
S2-3	Switch: toggle, DPDT	CH	7563-K4
T1-3	Transformer: input	T	JAF-1
T2-3	Transformer: output	T	JO-22
V1-3 V2-3	Tube: electron, 6072	GE	6072
V3-3	Tube: electron, 12AY7	GE	12AY7

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

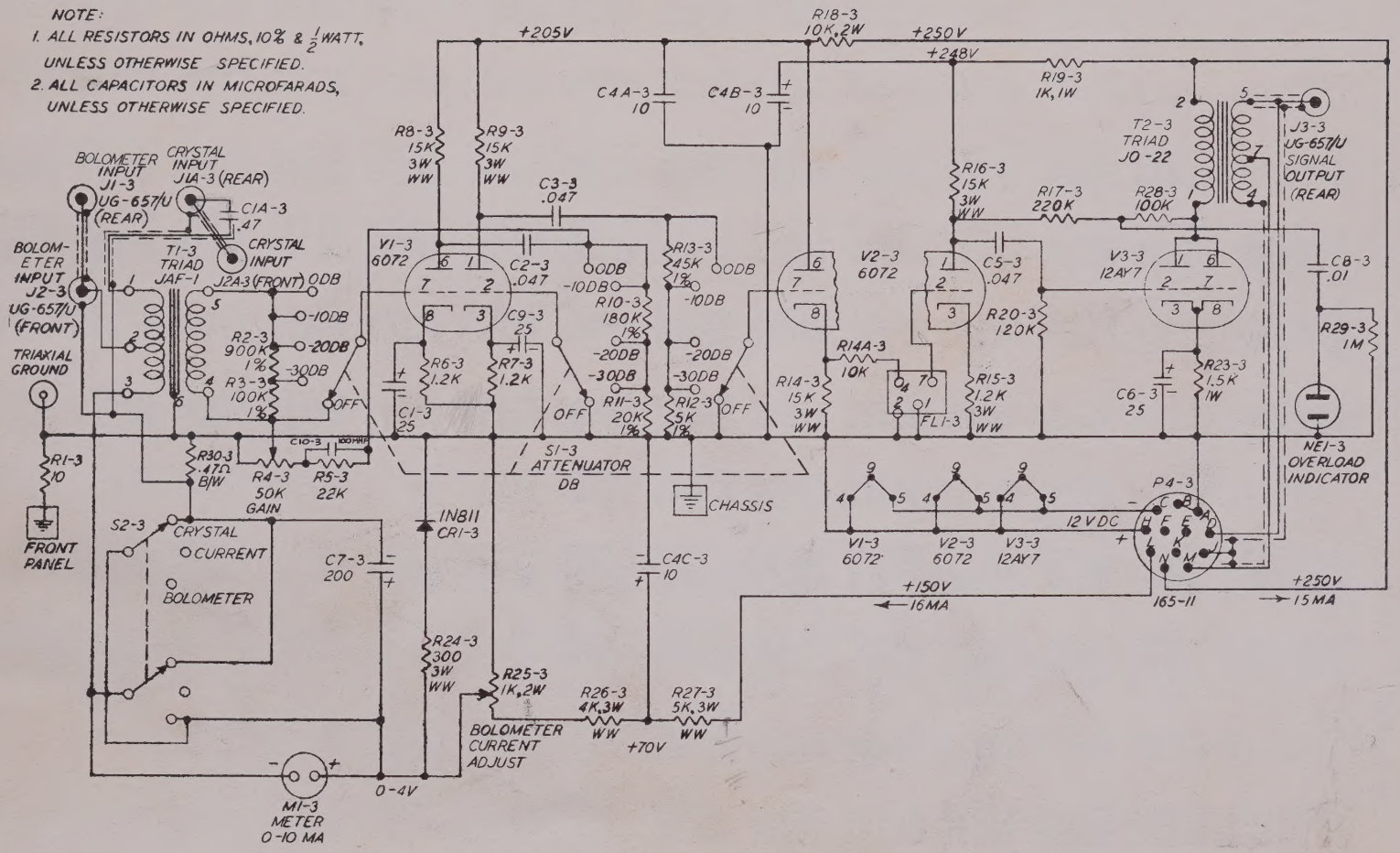

Figure 2. Schematic Diagram, Crystal-Bolometer Amplifier

CONVERSION OF VOLTAGE AND POWER RATIOS TO DECIBELS

The basic chart below indicates the number of decibels (db) corresponding to the listed ratios of voltage or power over the range of −20 to +20 db. For voltage or power ratios greater than those included in the chart, the ratio can be broken down into a product of two numbers, the value in db for each found separately, and the two results added. Example: To convert a power ratio of 2,000:1 to db, express 2,000 as 2×10^3; the number of db corresponding to a power ratio of 2 is very nearly 3, and the number of db for a power ratio of 10^3 is 30. Therefore, the power ratio of 2,000:1 is approximately 30 db + 3 db = 33 db. In the lower right-hand corner of the chart db values for voltage and power ratios of integral powers of 10 are given.

Voltage Ratio	Power Ratio	−db+	Voltage Ratio	Power Ratio	Voltage Ratio	Power Ratio	−db+	Voltage Ratio	Power Ratio	Voltage Ratio	Power Ratio	−db+	Voltage Ratio	Power Ratio
1.000	1.000	0	1.000	1.000	.447	.200	7.0	2.239	5.012	.200	.0398	14.0	5.012	25.12
.989	.977	.1	1.012	1.023	.442	.195	7.1	2.265	5.129	.197	.0389	14.1	5.070	25.70
.977	.955	.2	1.023	1.047	.437	.191	7.2	2.291	5.248	.195	.0380	14.2	5.129	26.30
.966	.933	.3	1.035	1.072	.432	.186	7.3	2.317	5.370	.193	.0372	14.3	5.188	26.92
.955	.912	.4	1.047	1.096	.427	.182	7.4	2.344	5.495	.191	.0363	14.4	5.248	27.54
.944	.891	.5	1.059	1.122	.422	.178	7.5	2.371	5.623	.188	.0355	14.5	5.309	28.18
.933	.871	.6	1.072	1.148	.417	.174	7.6	2.399	5.754	.186	.0347	14.6	5.370	28.84
.923	.851	.7	1.084	1.175	.412	.170	7.7	2.427	5.888	.184	.0339	14.7	5.433	29.51
.912	.832	.8	1.096	1.202	.407	.166	7.8	2.455	6.026	.182	.0331	14.8	5.495	30.20
.902	.813	.9	1.109	1.230	.403	.162	7.9	2.483	6.166	.180	.0324	14.9	5.559	30.90
.891	.794	1.0	1.122	1.259	.398	.159	8.0	2.512	6.310	.178	.0316	15.0	5.623	31.62
.881	.776	1.1	1.135	1.288	.394	.155	8.1	2.541	6.457	.176	.0309	15.1	5.689	32.36
.871	.759	1.2	1.148	1.318	.389	.151	8.2	2.570	6.607	.174	.0302	15.2	5.754	33.11
.861	.741	1.3	1.161	1.349	.385	.148	8.3	2.600	6.761	.172	.0295	15.3	5.821	33.88
.851	.724	1.4	1.175	1.380	.380	.145	8.4	2.630	6.918	.170	.0288	15.4	5.888	34.67
.841	.708	1.5	1.189	1.413	.376	.141	8.5	2.661	7.079	.168	.0282	15.5	5.957	35.48
.832	.692	1.6	1.202	1.445	.372	.138	8.6	2.692	7.244	.166	.0275	15.6	6.026	36.31
.822	.676	1.7	1.216	1.479	.367	.135	8.7	2.723	7.413	.164	.0269	15.7	6.095	37.15
.813	.661	1.8	1.230	1.514	.363	.132	8.8	2.754	7.586	.162	.0263	15.8	6.166	38.02
.804	.646	1.9	1.245	1.549	.359	.129	8.9	2.786	7.762	.160	.0257	15.9	6.237	38.90
.794	.631	2.0	1.259	1.585	.355	.126	9.0	2.818	7.943	.159	.0251	16.0	6.310	39.81
.785	.617	2.1	1.274	1.622	.351	.123	9.1	2.851	8.128	.157	.0246	16.1	6.383	40.74
.776	.603	2.2	1.288	1.660	.347	.120	9.2	2.884	8.318	.155	.0240	16.2	6.457	41.69
.767	.589	2.3	1.303	1.698	.343	.118	9.3	2.917	8.511	.153	.0234	16.3	6.531	42.66
.759	.575	2.4	1.318	1.738	.339	.115	9.4	2.951	8.710	.151	.0229	16.4	6.607	43.65
.750	.562	2.5	1.334	1.778	.335	.112	9.5	2.985	8.913	.150	.0224	16.5	6.683	44.67
.741	.550	2.6	1.349	1.820	.331	.110	9.6	3.020	9.120	.148	.0219	16.6	6.761	45.71
.733	.537	2.7	1.365	1.862	.327	.107	9.7	3.055	9.333	.146	.0214	16.7	6.839	46.77
.724	.525	2.8	1.380	1.905	.324	.105	9.8	3.090	9.550	.145	.0209	16.8	6.918	47.86
.716	.513	2.9	1.396	1.950	.320	.102	9.9	3.126	9.772	.143	.0204	16.9	6.998	48.98
.708	.501	3.0	1.413	1.995	.316	.100	10.0	3.162	10.000	.141	.0200	17.0	7.079	50.12
.700	.490	3.1	1.429	2.042	.313	.0977	10.1	3.199	10.23	.140	.0195	17.1	7.161	51.29
.692	.479	3.2	1.445	2.089	.309	.0955	10.2	3.236	10.47	.138	.0191	17.2	7.244	52.48
.684	.468	3.3	1.462	2.138	.306	.0933	10.3	3.273	10.72	.137	.0186	17.3	7.328	53.70
.676	.457	3.4	1.479	2.188	.302	.0912	10.4	3.311	10.96	.135	.0182	17.4	7.413	54.95
.668	.447	3.5	1.496	2.239	.299	.0891	10.5	3.350	11.22	.133	.0178	17.5	7.499	56.23
.661	.437	3.6	1.514	2.291	.295	.0871	10.6	3.388	11.48	.132	.0174	17.6	7.586	57.54
.653	.427	3.7	1.531	2.344	.292	.0851	10.7	3.428	11.75	.130	.0170	17.7	7.674	58.88
.646	.417	3.8	1.549	2.399	.288	.0832	10.8	3.467	12.02	.129	.0166	17.8	7.762	60.26
.638	.407	3.9	1.567	2.455	.285	.0813	10.9	3.508	12.30	.127	.0162	17.9	7.852	61.66
.631	.398	4.0	1.585	2.512	.282	.0794	11.0	3.548	12.59	.126	.0159	18.0	7.943	63.10
.624	.389	4.1	1.603	2.570	.279	.0776	11.1	3.589	12.88	.125	.0155	18.1	8.035	64.57
.617	.380	4.2	1.622	2.630	.275	.0759	11.2	3.631	13.18	.123	.0151	18.2	8.128	66.07
.610	.372	4.3	1.641	2.692	.272	.0741	11.3	3.673	13.49	.122	.0148	18.3	8.222	67.61
.603	.363	4.4	1.660	2.754	.269	.0724	11.4	3.715	13.80	.120	.0145	18.4	8.318	69.18
.596	.355	4.5	1.679	2.818	.266	.0708	11.5	3.758	14.13	.119	.0141	18.5	8.414	70.79
.589	.347	4.6	1.698	2.884	.263	.0692	11.6	3.802	14.45	.118	.0138	18.6	8.511	72.44
.582	.339	4.7	1.718	2.951	.260	.0676	11.7	3.846	14.79	.116	.0135	18.7	8.610	74.13
.575	.331	4.8	1.738	3.020	.257	.0661	11.8	3.890	15.14	.115	.0132	18.8	8.710	75.86
.569	.324	4.9	1.758	3.090	.254	.0646	11.9	3.936	15.49	.114	.0129	18.9	8.811	77.62
.562	.316	5.0	1.778	3.162	.251	.0631	12.0	3.981	15.85	.112	.0126	19.0	8.913	79.43
.556	.309	5.1	1.799	3.236	.248	.0617	12.1	4.027	16.22	.111	.0123	19.1	9.016	81.28
.550	.302	5.2	1.820	3.311	.246	.0603	12.2	4.074	16.60	.110	.0120	19.2	9.120	83.18
.543	.295	5.3	1.841	3.388	.243	.0589	12.3	4.121	16.98	.108	.0118	19.3	9.226	85.11
.537	.288	5.4	1.862	3.467	.240	.0575	12.4	4.169	17.38	.107	.0115	19.4	9.333	87.10
.531	.282	5.5	1.884	3.548	.237	.0562	12.5	4.217	17.78	.106	.0112	19.5	9.441	89.13
.525	.275	5.6	1.905	3.631	.234	.0550	12.6	4.266	18.20	.105	.0110	19.6	9.550	91.20
.519	.269	5.7	1.928	3.715	.232	.0537	12.7	4.315	18.62	.104	.0107	19.7	9.661	93.33
.513	.263	5.8	1.950	3.802	.229	.0525	12.8	4.365	19.05	.102	.0105	19.8	9.772	95.50
.507	.257	5.9	1.972	3.890	.227	.0513	12.9	4.416	19.50	.101	.0102	19.9	9.886	97.72
.501	.251	6.0	1.995	3.981	.224	.0501	13.0	4.467	19.95	.100	.0100	20.0	10.000	100.00
.496	.246	6.1	2.018	4.074	.221	.0490	13.1	4.519	20.42					
.490	.240	6.2	2.042	4.169	.219	.0479	13.2	4.571	20.89		10^{-3}	30		10^3
.484	.234	6.3	2.065	4.266	.216	.0468	13.3	4.624	21.38	10^{-2}	10^{-4}	40	10^2	10^4
.479	.229	6.4	2.089	4.365	.214	.0457	13.4	4.677	21.88					
.473	.224	6.5	2.113	4.467	.211	.0447	13.5	4.732	22.39		10^{-5}	50		10^5
.468	.219	6.6	2.138	4.571	.209	.0437	13.6	4.786	22.91	10^{-3}	10^{-6}	60	10^3	10^6
.462	.214	6.7	2.163	4.677	.207	.0427	13.7	4.842	23.44		10^{-7}	70		10^7
.457	.209	6.8	2.188	4.786	.204	.0417	13.8	4.898	23.99	10^{-4}	10^{-8}	80	10^4	10^8
.452	.204	6.9	2.213	4.898	.202	.0407	13.9	4.955	24.55		10^{-9}	90		10^9
										10^{-5}	10^{-10}	100	10^5	10^{10}
											10^{-11}	110		10^{11}
										10^{-6}	10^{-12}	120	10^6	10^{12}

SCIENTIFIC-ATLANTA, INC.

2162 PIEDMONT RD., N. E. • ATLANTA 9, GA.

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